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Hemisphere side of damage and encoding capacity

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This study was designed to examine whether normal information processing does engage both hemispheres of the brain regardless of sensory channel (i.e., auditory or visual), and whether an opportunity for dual encoding (verbal and visual) was advantageous for patients with unilateral brain damage. It compared memory for verbal material presented in the visual and auditory modalities among three groups: right hemisphere brain damaged stroke patients (RBD), left hemisphere brain damaged stroke patients (LBD), and neurologically intact control subjects.

Only control and LBD subjects benefitted from the visual presentation compared with auditory. Controls did gen-

erally better on both modes than either stroke group. These data suggest that normal information processing does engage both hemispheres of the brain, and that the capacity to use visual and verbal encoding aids memory for LBD patients and normal controls, but that RBD patients are impaired in their ability to use visual encoding to enhance their verbal memory.

HEMISPHERE SIDE OF DAMAGE AND ENCODING CAPACITY

by

MARGARET ELLEN DAVIS

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TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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INTRODUCTION

The concept of hemispheric specialization in the brain has excited scientists, educators, therapists, and the general public. Researchers have been involved in attempts to categorize all sorts of behavior and learning into right or left hemispheric functions.

Specialization has sometimes been believed to be material specific with verbal material being dealt with by the left hemisphere and visuospatial material being dealt with by the right (Milner, 1971; Warrington and James, 1967; Newcombe, 1969; McFie, 1969).

Some neuropsychologists began pointing out that differences between right and left hemispheric functions may be in how each side is organized rather than due to material specificity (DeRenzi and Faglioni, 1967; Hécaen and Angelergues, 1963). Differences between the two hemispheres were thought not to be only a matter of degree, but also a matter of different mechanisms underlying the performance (DeRenzi, Faglioni, and Spinnler, 1968). The left side's verbal superiority is thought not to be due to a verbal program or greater ability to handle auditory stimuli and the right side's major contributions to drawing and construction are not attributable to a specific ability to process visuospatial data. Instead each hemisphere processes all the information that reaches the cortex, but each in its own way (Berlucchi, 1974; Broadbent, 1974; Larsen, Skinhøj, and Lassen, 1978).

The right side of the brain may be more broadly organized than the left at the cellular level. The left processes discrete data bits that characterize verbal stimuli perceived in visual, auditory, and sometimes tactile strings. Left hemisphere processing may be thought of as a digital computer which proceeds on a linear, bit-by-bit basis. The right hemisphere works more like an analog computer, processing in terms of patterns or configurations. Most verbal functions are mediated by the left side because they can be processed in a straight line, item-by-item. Pictures, music, story plots, and blueprints are more configurational and can better be handled by the right hemisphere (lezak, 1982).

The literature is full of contradictions and ambiguities. Investigators have noted this and wondered if both hemispheres do process all information or at least contribute to the processing of all information. While some find it appealing to believe that verbal memory is a left hemisphere function and configural memory is a function of the right hemisphere, evidence fails to support a strict separation of functions.

Samuels and her colleagues reportedly found that subjects with both right and left temporal lobectomies showed severe deficits in auditory memory for verbal material but normal performance on visuoverbal and configural tasks (Hécaen and Albert, 1967). Dee (1971) found that right hemisphere damaged patients were not significantly more impaired in visuoconstructive performance than were left hemisphere damaged patients. One study shows that left hemisphere/aphasic patients' ability to retain verbal information is impaired whether that information is presented visually or auditorily while patients with right hemisphere damage show verbal memory impairments when the material is presented visually, but not auditorily (Schwartz, Shipkin, and Cermak, 1979).

There are a number of observations that indicate that the two hemispheres work together, handling tasks and stimuli (Larsen, et al., 1978). Benton, Van Allen, and Hamsher (1975) have shown that about the same proportions of left hemishere damaged patients with aphasia perform at a defective level on a facial recognition task, as do right hemisphere damaged patients generally. Another study using patients with unilateral temporal lobectomies and normal control subjects involved recalling the names of 25 simple object pictures. After 24 hours the normal subjects recalled nearly twice as many pictures as either temporal lobe group. Milner (1978) concluded that recall of a past experience relies at least in part on the participation of both hemispheres during initial coding. A study of blood flow in the right and left hemispheres indicates that the performance of spoken speech involves activation of both hemispheres (Larsen, et al., 1978).

The exact mechanisms that produce integration between the two hemispheres are not known. Probably no single mechanism is responsible. Each hemisphere seems to have some inhibiting effect on the other and they also work synergistically in processing the same data by the two different processing systems (Lezak, 1982). We do know that considerable communication does occur between the two hemispheres. The corpus callosum and two smaller transverse fiber bundles provide direct communication. Myers and Sperry reportedly showed the role of the corpus callosum in the transfer of visual learning from one hemisphere to the other in normal subjects (Brodal, 1981; Bogen and Bogen, 1969). Indirect communication takes place by means of pathways through the lower brain centers (Jeeves, 1965).

Although hemispheric specialization is an interesting and important concept, integration is equally interesting and important. Most of us have intact brains and our behavior is the result of integrated brain function. Understanding that both hemispheres normally process all stimuli is important knowledge for educators and therapists in rehabilitation settings. Good teachers have long used pictures and words, known now as audio-visual aids, and now neuropsychological research is explaining why it works. Learning of almost any idea is likely to be better if both methods of presentation are used.

Paivio's dual processing, or dual coding, theory sees imaginal and verbal techniques as alternative means of encoding, and explains that memory of concrete nouns will be greater if people employ both verbal and visual encoding strategies. While visual imagery enhances verbal memory, so does verbal labeling enhance visual memory (Paivio, 1971) although imaginal processing seems to be a more symmetrical activity than verbal processing which is more lateralized to the left hemisphere (Binder, 1978).

STATEMENT OF THE PROBLEM

This study is to determine whether normal information processing engages both hemispheres of the brain regardless of sensory channel (i.e., verbal or pictorial). If this is true, then differences in performance will be observed between brain damaged and normal control subjects.

The other target of this study is to establish whether an opportunity for dual encoding (verbal and visual) would be advantageous for patients with unilateral brain damage. The concept of dual coding, a hypothesis provided by Paivio (1971), states that stimuli encoded both verbally and visually will be remembered better than material encoded only verbally. While previous research has supported the hypothesis for neurologically intact people, it is not clear that brain-damaged people also benefit from stimuli designed to enhance dual rather than single coding. Patients with right brain damage and visuoperceptual information processing deficits might not obtain the same benefit from an opportunity for visual encoding as would patients without such deficits. A memory test using verbally encodable visual stimuli would provide an opportunity for dual coding and make dual coding more likely than presenting material through the auditory modality.

I hypothesized that visual presentation of easily named objects would result in better recall than auditory presentation. I also hypothesized that only normal subjects and left brain damaged patients would perform better on visual than on auditory recall, with right brain damaged subjects not differing across modalities.

I predicted that the performance of control subjects would be generally superior to both stroke groups, as the controls process all information with an intact brain while the stroke patients are working with a compromised hemisphere.

The left hemisphere damaged group was expected to do less well than either the controls or the right hemisphere damaged group on the verbal presentation and the right hemisphere damaged group was expected to do less well than the controls on the verbal presentation. Finally, the left hemisphere damaged group was expected to benefit more from the visual presentation than the right hemisphere damaged group.

METHOD

SUBJECTS

Three 15-member groups of white right-handed subjects were composed of right hemisphere brain damaged stroke patients (RBD), left hemisphere brain damaged stroke patients (LBD), and neurologically intact medical and surgical controls. Stroke chronicity was no less than one year and was equated between RBD and LBD groups, with an average chronicity of four years. Only patients suffering from their first stroke were included. Stroke patients were found through the Portland, Oregon area Stroke Club, the Portland Veterans Administration Medical Center (PVAMC), and through the Speech and Hearing Clinic associated with University of Oregon Health Sciences Center.

The control subjects were all patients in the PVAMC or out-patients from the VA Out-Patient Clinic. Many were from medical or surgical wards or from the Chronic Pain Unit. They were all neurologically intact with no history of head trauma or stroke. Included in the medical problems suffered by the controls were diabetes, cancer, arthritis, and chronic back pain.

Each group consisted of 14 men and one woman. No subject had a history of alcoholism or substance abuse. All subjects were 62 years old or younger. Mean age was 56.76 years and was not significantly different among groups. Mean educational level was 12.5 years and did not differ among groups. Vocabulary level, as measured by the Employee

Aptitude Survey Verbal Comprehension Test (Ruch and Ruch, 1963) was also similar among groups, with group means ranging from 20.00 to 20.67 (out of a possible score of 30). Table I presents the means and standard deviations of the relevant demographic and selection variables. One way analyses of variance were conducted across the three groups and showed that there were no significant differences for age, education, or vocabulary ability.

Before any person was made a test subject, he or she had to succeed on the following two tasks (Appendix B):

1) Repeating after the investigator the names of ten simple objects;

2) Identifying verbally ten simple objects printed on cards.

Success on these two tasks ensured that a subject was not verbally or visuospatially impaired to the extent that the test procedure itself was confounded. No prospective subject was rejected on this basis.

MATERIALS

The Employee Aptitude Survey Verbal Comprehension Test (Ruch and Ruch, 1963) is a paper-and-pencil multiple-choice vocabulary test consisting of 30 items. A word is listed followed by four other words. The subject is asked to read the first word and select the one of the four others which means the closest to the first word and make a mark by that word.

The following two forms of Rey's Verbal Learning Test

Table 1

Means and Standard Deviations of Demographic Variables and Vocabulary for the Three Groups

		Age	Education	EAS Vocabulary	Chronicity
RBD	M	58.27	12.47	20.13	3.73
	SD	(3.39)	(2.07)	(4.55)	(2.87)
LBD	M	57.40	12.27	20.00	4.27
	SD	(5.33)	(1.44)	(3.91)	(2.91)
Controls	M	54.60	12.60	20.67	NA
	SD	(7.22)	(2.13)	(3.62)	NA

(Rey, 1959) (Appendix A) were used:

1) Rey's Auditory Verbal Learning Test (AVLT): consists of two lists of 15 simple nouns. The first word list (List A) is read to the subject by the investigator at a rate of about one per second. At the end of this oral presentation the subject recalls verbally as many of the words as he or she can in any order while the investigator records them (Trial I). This entire procedure, using the same Word List A, is repeated for Trials II-V. A second word list (List B) is then presented which the subject also verbally recalls one time (Trial B). Following Trial B the subject recalls the first Word List A with no repeat presentation of it (Trial VI).

2) Visual Verbal Learning Test (VVLT) (Lezak, 1976): consists of two sets of 15 cards with pictures of simple objects printed on them. The first set of cards (Set A) is presented to the subject at a rate of about one per second with no verbal presentation. The subject then recalls as many of the pictures as possible verbally while the investigator records the responses. The format continues identical to that used with the AVLT except using the visual presentation.

Standard Instructions These instructions preceded the AVLT test procedure:

> I am going to read a list of words to you. When I'm finished I want you to repeat as many of the words as you can remember, in

> any order. Do you have any questions?
> Are you ready?

At this point the investigator reads List A at a rate of about one per second, then asks the subject to recall as many words as he or she can while the investigator records them. At the end of Trial I, further instructions were:

> Now I am going to read the same list of words to you and I want you to repeat as many as you can remember, INCLUDING the ones you recalled last time. Ready?

The investigator reads List A again, recording the words the subject recalls at the end of each trial. These instructions follow Trials I-IV. The instructions for Trial B:

> Now I am going to read a different list of words and when I'm finished I want you to repeat as many of this new list as you can.

The instructions for Trial VI follow the subject's recall of the second word list (List B) with no repeat of Word List A:

> Now please try to remember as many of the first word list I read to you and repeat those words to me.

Identical instructions to these are used for the VVLT, except using "set of pictures" instead of "list of words". The subject did not begin verbalizing aloud until all the pictures had been shown.

When a subject asked if he or she had recalled all the words they were told; when a subject had recalled all 15 words or pictures he or she was told the task was completed.

PROCEDURE

All subjects were first given the tasks of repeating words and names of pictures (Appendix B) at the time of history taking, which occurred at least one week prior to the actual test procedure. The subjects were first given the Employee Aptitude Survey Verbal Comprehension Test (EAS) (Ruch and Ruch, 1963) at the time of the actual test procedure. This vocabulary test was not timed but all subjects finished within ten minutes.

All subjects were then given the two forms of Rey's Verbal Learning Test (Appendix A), the AVLT and the VVLT. The order of presentation of the AVLT and VVLT was counterbalanced so that approximately equal numbers of subjects within each group received the AVLT or the VVLT first.

The tests were administered individually to each subject in a quiet place in the subject's home, or in a private room on the patient's ward in the hospital. Each subject was reassured he or she could stop the procedure at any time and could drop out of the study with no threat to VA benefits or medical care. The test procedure lasted a total of 45 minutes.

Scores reflect the total number of correctly recalled words or pictures in any order on each trial, disregarding any extra words inserted by the subject.

RESULTS

Four of the seven trials were examined: Trial I, an indication of immediate recall; Trial V, which shows a learning curve; Trial B, which is recall in circumstances of proactive inhibition; and the last trial which measures delayed recall (Lezak, 1976). Means and standard deviations of the AVLT and VVLT for the three groups on these four trials are shown in Figure II.

The data were subjected to a 3-factor mixed design analysis of variance (3-way, repeated on 2) with repeated measures on trials and modality, and group as a between-subjects factor. The three main effects, groups x mode, groups x trials, and trials x mode, were all significant (F's, 2,42, ≥ 4.54, p .01), as were all two-way interactions (F's, 1,42, ≥ 7.67, p .05). Of special interest was the interaction of groups by modality, $F(2,42)=7.67$, $p<.05$, and the main effect of modality, $F(1,42)=50.82$, $p<.0001$. Figure I presents the average score of the four trials comparing each group's performance on the AVLT and VVLT. These results indicate that the visual modality was easier than the auditory, but that the amplitude of the effect was not the same for all groups. An analysis of simple main effects revealed that the effect of modality of presentation was highly significant for the normal controls, F $(1,42)=24.31$, $p<.0001$, and for the LBD group, $F(1,42)=30.01$, $p<.0001$, but there was no significant difference in modalities for the RBD group. The LBD and RBD groups were not significantly different on auditory presentation. Controls did significantly better on both the AVLT and the VVLT than either the LBD or the RBD groups (F's, 1, 42, ≥ 15.67, $p < .001$).

TABLE II

AVLT and VVLT Means and Standard Deviations

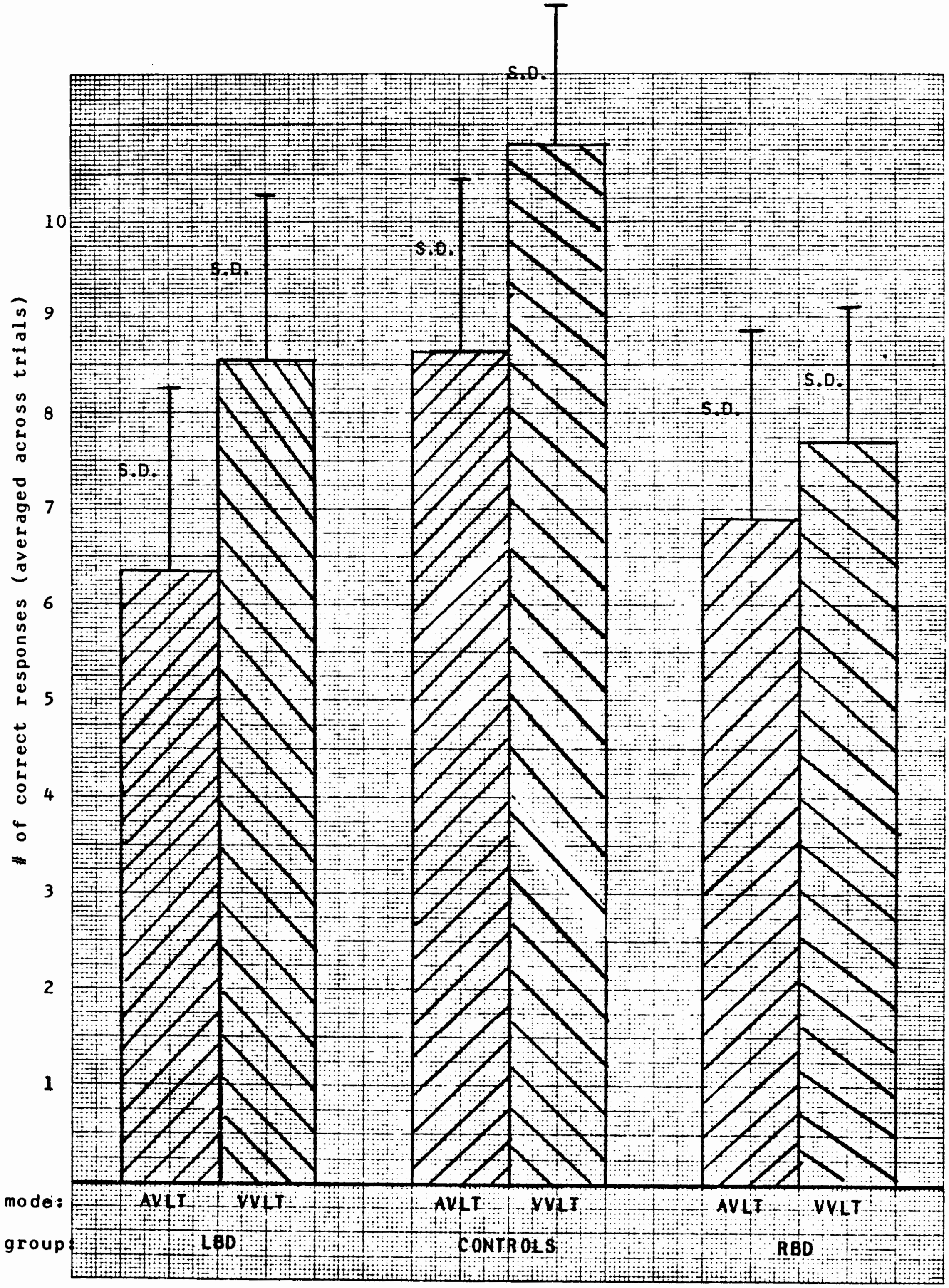
		Trial I	Trial V	Trial B	Trial VI
Controls					
AVLT	M	6.33	13.20	4.67	10.40
	SD	(2.26)	(1.47)	(1.80)	(1.92)
VVLT	M	9.07	14.47	6.00	13.73
	SD	(1.53)	(1.30)	(1.69)	(1.53)
RBD					
AVLT	M	6.20	10.13	4.27	7.00
	SD	(1.61)	(1.81)	(1.53)	(2.88)
VVLT	M	7.27	11.47	3.60	8.33
	SD	(.88)	(1.19)	(1.12)	(2.58)
LBD					
AVLT	M	5.00	10.47	3.67	7.27
	SD	(2.00)	(2.17)	(1.11)	(2.49)
VVLT	M	6.07	12.53	5.47	10.13
	SD	(1.16)	(2.56)	(1.13)	(2.17)

FIGURE I

Average Scores Across Trials of Each Group

Comparing AVLT and VVLT

FIGURE I



GROUP X MODE GRAPH

DISCUSSION

This study compared right hemisphere damaged stroke patients (RBD), left hemisphere damaged stroke patients (LBD), and neurologically intact medical and surgical control subjects on two forms of Rey's Verbal Learning Test (Rey, 1959). It was designed to compare memory for auditorily presented nouns and pictorially presented nouns and also to see whether an opportunity for dual encoding (verbal and visual) was advantageous for patients with unilateral brain damage.

Although groups were equated for age, education, race, and vocabulary ability, and, between the stroke groups, chronicity, significant differences in memory ability were found.

The primary question I was exploring was whether normal information processing does engage both hemispheres of the brain regardless of sensory channel. On both the auditory and the visual presentations of material in this study, the control group did significantly better than either stroke group. This indicates that, indeed, both sides of the brain may be required for optimal information processing. The controls were using two intact hemispheres while the stroke groups each were functioning with one impaired hemisphere.

I predicted that the control and the LBD groups would perform significantly better using the visual rather than the verbal mode of presentation because the pictures would allow these groups to encode the material two ways. The RBD groups was not expected to benefit as much with the visual presentation. This prediction was borne out by the data and I conclude that RBD subjects are impaired in their ability to use visual encoding to enhance their verbal memory.

The LBD group was expected to do significantly more poorly than either the RBD or the control groups on the auditory presentation. Although the LBD and RBD groups did less well than the controls, there was no significant difference between the LBD and RBD groups. The RBD group did not perform as well on the AVLT as I anticipated. This is puzzling and a repeat study of RBD subjects' performance on the AVLT along with other memory tests would be helpful in explaining this.

I hypothesized that the LBD group would do better than the RBD group but still less well than the controls on the visual stimuli. Similarly, I expected that the LBD group would improve more than the RBD group would. The data support these hypotheses. Visual stimuli allowed the LBD group to use intact visuoperceptual processing and thereby to enhance their verbal memory.

The control subjects in this study did better than either stroke group on both auditorily and visually presented material. Benton and his associates have shown that LBD patients with aphasia perform at a defective level on a facial recognition task (Benton, et al., 1975), as do RBD patients in general. In Milner's study (1978) where subjects recalled the names of 25 simple object pictures, the normal subjects recalled almost as many pictures after a 24-hour interim period as on the immediate recall trial while both right and left temporal lobectomy groups recalled half or fewer the number of words that the normals did.

This finding, that brain damaged patients' performances are poorer than normal subjects', supports the theory that both hemispheres normally process all stimuli, whether purely verbal, or both verbal and visual. Paivio (1971) applies this theory to normal adults, and his research supports that when material is presented in a dually encodable mode, memory is improved. This study, whose data show that normal subjects do better with the visual presentation, also support Paivio's findings.

This study and the previous study conducted by Lezak, (1982), also using the AVLT and VVLT, both found that LBD patients improved more with the presentation of pictures than did RBD patients. These studies support the notion that when LBD patients are given the opportunity to use visuoperceptual processing they will do so and their verbal memory will be subsequently enhanced.

CLINICAL IMPLICATIONS

Since memory problems are common complaints among brain damaged populations, the knowledge that visual aids help left hemisphere damaged patients' verbal recall is important. By matching up verbally presented material with visual representations LBD groups may recall words nearly as well as normals retain verbally presented material.

Normal populations with intact brains also benefit from dual encoding. Recall of visually presented nouns is significantly better than verbally presented nouns.

FUTURE RESEARCH

Although this study helps clarify some questions about dual encoding and the populations it benefits most, it also leaves several areas unexplored. One direction a future study might go is to determine if concepts and stories are also better recalled when presented in a dually encodable manner. The significance of such a study for brain damaged pupils could be startling. In my study, the LBD group did as well with dually encodable material as the controls did with verbally presented material. If a LBD population could improve to this level with concepts, stories, or even numbers as in mathematics, they would be functioning at a nearer to normal level. Such a study combined with a study which investigated long-term effects of dual encoding over periods of weeks or months would be quite interesting.

Finally, my study examines assigning pictorial representations to verbally encodable nouns, but does not experiment with memory of nonsense syllables which are not visually encodable. Rey (1959) found that normal young adults' immediate recall of readily verbalized visually presented common items slightly exceeded recall of more abstract words alone. Neurologically impaired adults showed a greater difference in their increased ability to recall verbalizable items compared to words alone. Perhaps the time has come to expand such a study to more fully explore Paivio's dual coding theory.

SUMMARY

This study compared memory for verbal material presented in the visual and auditory modalities among three groups: right hemisphere brain damaged stroke patients (RBD), left hemisphere brain damaged stroke patients (LBD), and neurologically intact control subjects. It was designed to examine whether an opportunity for dual encoding (verbal and visual) was advantageous for patients with unilateral brain damage.

Controls performed better than either stroke group on both tasks. Only the control subjects and the LBD group benefitted from the visual presentations compared with auditory on this verbal memory task. I conclude that visual stimuli allowed the LBD and control groups to use intact visuoperceptual processing whereas the RBD group did not perform better because of impaired visuoperceptual processing. Memory of verbal material is enhanced when dual encoding is possible. The control group's superior performance with the use of pictures suggest that memory is aided by 2-channel stimulation.

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APPENDIX A

Development of the VVLT

Using a list of the most frequently used English words (Carroll, et al., 1971), nouns were picked out and those already appearing in the AVLT were discarded. From the remaining more frequently used nouns, those which could be pictorially represented on cards were chosen. 60 of these simple objects printed on small cards were shown to 100 staff and patients at the Portland VA Medical Center. Those which were called the same name with 100% consistency were retained and all others were discarded. Fifteen of the cards which were kept were designated Picture Set A for the VVLT, and fifteen were designated Picture Set B.

VVLT

List A	List B	Alternate
feet	bus	man
boy	corn	arm
sun	pie	window
car	wheel	cat
table	coat	rocket
tree	bed	log
hand	roof	flag
fire	shell	door
horse	cow	penny
ball	fence	ladder
Indian	purse	cherries
heart	hammer	eggs
bread	bone	rope
radio	fruit	star
king	kitchen	wagon

List A	List B	Alternate
drum	desk	book
curtain	ranger	flower
bell	bird	train
coffee	shoe	rug
school	stove	meadow
parent	mountain	harp
moon	glasses	salt
garden	towel	finger
hat	cloud	apple
farmer	boat	chimney
nose	lamb	button
turkey	gun	key
color	pencil	dog
house	church	glass
river	fish	butter

(Rey, 1959; taken in part from Lezak, 1976).

APPENDIX B

Development of the Pre-Test Word and Picture Lists

Using the first 2000 words in a list of the most frequently used English words (Carroll, et al., 1971), nouns were picked out and those already appearing in the AVLT and the VVLT were discarded. From the remaining more frequently used nouns, 50 were chosen, 25 of which could be pictorially represented on cards. The 25 not printed on cards were read to neurologically intact staff and patients at the Portland VA Medical Center and those people repeated the words back. Any words that any person repeated back incorrectly or had difficulty in pronouncing were discarded. The 25 nouns which were pictorially represented on cards were shown to another sample of 100 staff and patients and only those cards which were named the same name by all 100 people were kept. 10 of each of the words and pictures which 100 people were able to pronounce correctly or identify correctly were chosen for the pre-test. These two lists were given to prospective subjects at least one week before the actual test procedure, and only those succeeding 100% on both tasks were used as test subjects.

Pre-test Words	Pre-test Pictures
city	whistle
family	football
letter	crutches
voice	piano
winter	feather
floor	saddle
center	lion
plant	pineapple
music	fork
teacher	airplane